

IN THE CLAIMS:

- 1 1. (Currently Amended) A method of automatically calibrating a water distribution
2 model of a water distribution network, including the steps of:
- 3 (A) selecting calibration parameters including link status and at least one
4 or more of pipe roughness and junction demand, and link status;
- 5 (B) collecting field observed data including a pipe flow measurement and a
6 junction pressure measurement for at least one point in the water distribu-
7 tion network, and including corresponding loading conditions and bound-
8 ary conditions that existed in the network when said field observed data
9 was collected;
- 10 (C) generating a population of trial solutions that comprise a set of calibration
11 results, using a genetic algorithm; and
- 12 (D) running multiple hydraulic simulations of each trial solution to obtain a set
13 of predictions of pipe flows and junction pressures at selected points in the
14 network, corresponding to the different loading conditions and associated
15 boundary conditions when the field observed data was collected.
- 1 2. (Currently Amended) The method of automatically calibrating a water distribu-
2 tion model as defined in claim 1, including performing a calibration evaluation including
3 the steps of:
- 4 (A) computing a goodness-of-fit value for each calibration solution by using
5 one or more of the following objective functions:
- 6 1. minimizing the sum of difference square;
- 7 2. minimizing the sum of absolute differences; and
- 8 3. minimizing maximum difference;
- 9 (B) ~~assigning the goodness-of-fit value for each solution as the fitness for that~~
10 ~~entry into a genetic algorithm; and~~ defining the difference as the distance

11 between field observed values and model simulated values including flows
12 and pressure head/water levels; and
13 converting both flow differences and head level differences into an
14 equivalent score using two conversion factors, including point per unit
15 pressure head difference and point per unit flow difference; and
16 (C) searching for optimized solutions using said a genetic algorithm and calcu-
17 lating overall goodness of fit over the field data sets selected for a model
18 calibration run, and assigning an overall goodness of fit to each solution as
19 a fitness entry into a genetic algorithm to search for optimized solutions.

1 3. (Currently Amended) The method of automatically calibrating a water distribu-
2 tion model as defined in claim 2, including the further step of:

3 (A) selecting a weighting function for at least one of said field observed data
4 measurements, said weighting function formulated as a normalized
5 weighting factor of observed pressure heads and flows; and

6 (B) selecting as said weighting factors one of a linear, square, square root or
7 log function of the ratio of individual values (flow or hydraulic pressure)
8 to a sum of the observed values (flows or hydraulic pressures); and

9 ~~(B)~~(C) applying said weighting function when running said calibration evaluation
10 to determine said goodness-of-fit value.

1 4. (Original) The method of automatically calibrating a water distribution model, as
2 defined in claim 1, including the further step of:

3 selecting as said loading condition, at least one water demand loading at a prede-
4 termined time of day, corresponding to a time of day when a field observed data meas-
5 urement has been made.

1 5. (Original) The method of automatically calibrating a water distribution model, as
2 defined in claim 4, including the further step of selecting multiple loading conditions rep-

3 resenting demand loading at various times of day when field observed data measurements
4 have been made.

1 6. (Original) The method of automatically calibrating a water distribution model as
2 defined in claim 1 wherein said boundary conditions include water storage tank levels,
3 pressures control valve settings and pump operation speeds.

1 7. (Original) The method of automatically calibrating a water distribution model as
2 defined in claim 1 including the further step of:
3 after said optimized set of calibration data is obtained, making manual adjust-
4 ments to this information for said water distribution model calibration.

1 8. (Original) The method of automatically calibrating a water distribution network
2 model as defined in claim 1, including the further step of performing a sensitivity analy-
3 sis by varying model input parameters over a predetermined range and observing the re-
4 sponse thereto of said model.

1 9. (Original) The method of automatically calibrating a water distribution network
2 model as defined in claim 8 including the further step of adjusting the collection of field
3 observed samples based upon the results of said sensitivity analysis.

1 10. (Currently Amended) ~~A system embodied in a software program~~A computer
2 readable medium containing executable program instructions for automatically calibrat-
3 ing a water distribution model of a water distribution network that has links that include
4 pipes and junctions, ~~the system comprising~~the executable program instructions compris-
5 ing program instructions for:

6 (A) ~~a generating a graphic user interface coupled with an associated work sta-~~
7 ~~tion into~~ by which the user may enter data concerning field observed
8 measurements for the network, and may make other entries and selections;

- 9 (B) a calibration module ~~having software programming that~~ formatted to pro-
10 duces calibration information for a water distribution model constructed
11 from user-selected calibration parameters that include at least one of pipe
12 roughness, junction demand information, including demand groups,
13 roughness groups, and link status;
- 14 (C) a genetic algorithm module coupled to said calibration module and said
15 user interface such that information about said calibration parameters, and
16 user-entered field observed data, including selected field data sets that in-
17 clude calibration target data and boundary data, may be operated upon to
18 produce a population of trial solutions, ~~including calibrated pipe flows~~
19 ~~and hydraulic grade line pressures for predetermined portions of said net-~~
20 ~~work and said graphic user interface further being configured to allow a~~
21 user to select goodness-of-fit criteria, a weighting functions, and or more
22 genetic algorithm parameters and a number of top trial solutions; and
- 23 (D) a hydraulic network simulation module ~~coupled in communicating rela-~~
24 ~~tionship~~ with said genetic algorithm module such that top solutions gener-
25 ated by said genetic algorithm module can be run by said hydraulic net-
26 work simulation module and saved to be used to predict actual behavior
27 of said network.

1 11. (Currently Amended) ~~The system~~ The computer readable medium as defined in
2 claim 10, ~~wherein said calibration module further includes calibration evaluation pro-~~
3 ~~gramming that computes a goodness-of-fit value for each trial solution generated by said~~
4 ~~genetic algorithm~~ wherein multiple calibration runs are created including a new calibra-
5 tion run being created as a child of a previous calibration run said child calibration run
6 inheriting the previously selected calibration settings and apparent calibration runs.

1 12. (Currently Amended) ~~The system~~ The computer readable medium as defined in
2 claim 11, wherein said genetic algorithm module further includes optimization program-

3 ming that repetitively computes successive generations of solutions based upon said fit-
4 ness information calculated by said calibration module to at least one optimal solution,
5 and multiple top solutions being saved at the end of each optimized calibration run and
6 all calibration settings and top solutions are persisted in such a manner that said user can
7 review and retrieve any calibration run previously performed.

1 13. (Currently Amended) ~~The system~~The computer readable medium as defined in
2 claim 10 further comprising:
3 a database including information regarding water distribution networks for constructing
4 models of said networks.

1 14. (Currently Amended) ~~The system~~The computer readable medium as defined in
2 claim 10 wherein said user interface further allows a user to enter information regarding
3 alternative demand loadings, representing a demand for water supply at a given point in
4 time, at a given location in the network.

1 15. (New) A method as described in claim 1 wherein link status includes the opera-
2 tional status being opened or closed of one or more of pipes, valves and, as being on or
3 off for pumps, in the water distribution model of the water distribution network that is
4 being calibrated.

1 16. (New) The method as defined in claim 1 further comprising the step of:
2 computing a roughness value, roughness multiplier, demand multiplier and link
3 status.

1 17. (New) A method of calibrating a water distribution model including the steps of:

collecting calibration target data and matching for the calibration one or more of the following:

pipe flows, pump flows, pressure at any location in a system, tank water levels and fire hydrant test pressure;

collecting calibration boundary condition data including reservoir water level, tank hydraulic head measurements, pump operation speed, fire hydrant test flow, fire hydrant test time, and link status; and

including a time of day for both calibration target data and boundary condition data thus representing systematic conditions at that time, whereby a complete set of data is collected to represent the overall system conditions at any given time of day.

18. (New) The system as defined in claim 10 wherein a calibration run can be terminated by selecting calibration stop criteria including maximum number of trials, minimum required goodness-of-fit, and maximum number of non-improvement generations of genetic algorithm optimization.

19. (New) The system as defined in claim 10 including each top solution being presented in a table setting forth one or more of:

- 1) comparison of calibrated and original roughness coefficients for each group of pipes in each individual pipe;
- 2) comparison of calibrated and original demand for each demand group and each node;
- 3) comparison of calibrated and original status of operable links;
- 4) comparison of calibrated and original hydraulic grade line, pressure head, plus node evaluation; and
- 5) comparison of calibrated and original flows.

20. (New) The system as defined in claim 10 further comprising each top solution being presented in a correlation graph of the observed value versus the calibrated value of link, flows and hydraulic gradelines.

1 21. (New) The system as defined in claim 10 further comprising means for exporting
2 any selected top solution as a scenario into said hydraulic module, which includes one or
3 more of the following data sets:

- 4 1) calibrated roughness coefficients for each pipe;
- 5 2) calibrated demand for each node;
- 6 3) calibrated status for each operable link; and
- 7 4) boundary conditions used for producing such calibration solution.

1 22. (New) A method of manually calibrating a water distribution model of a water
2 distribution network, including the steps of:

- 3 (A) selecting calibration parameters including link status and one or more of
4 pipe roughness and junction demand;
- 5 (B) collecting field observed data including a pipe flow measurement and a
6 junction pressure measurement for at least one point in the water distribu-
7 tion network, and including corresponding loading conditions and bound-
8 ary conditions that existed in the network when said field observed data
9 was collected;
- 10 (C) running multiple hydraulic simulations of each trial solution to obtain a set
11 of predictions of pipe flows and junction pressures at selected points in the
12 network, corresponding to the different loading conditions and associated
13 boundary conditions when the field observed data was collected;
- 14 (D) computing a goodness-of-fit value for each calibration solution by using
15 one or more of the following objective functions:
 - 16 1. minimizing the sum of difference square;
 - 17 2. minimizing the sum of absolute differences; and
 - 18 3. minimizing maximum difference; and
- 19 (E) defining the difference as the distance between field observed values and
20 model simulated values including flows and pressure head/water levels.